Q 3: Cold Molecules 1

Time: Monday 10:30–13:00 Location: BAR Schön

Q 3.1 Mon 10:30 BAR Schön

Ultracold and dense samples of ground-state molecules — •Johann Georg Danzl, Manfred Mark, Elmar Haller, Lukas Reichsöllner, and Hanns-Christoph Nägerl — Institut für Experimentalphysik, Universität Innsbruck, Innsbruck, Austria

We produce ultracold and dense samples of rovibrational ground state (RGS) molecules near quantum degeneracy in the presence of an optical lattice. We first associate Cs_2 Feshbach dimer molecules out of a lattice-based Mott-insulator state loaded from an atomic Bose-Einstein condensate (BEC) of Cs atoms and then coherently transfer the molecules to the RGS by a four-photon STIRAP process. We discuss improvements to reach higher transfer efficiencies and the next steps towards the production of a BEC of dimer molecules. The work is supported by the Austrian Science Fund FWF in the framework of project P 21555-N20.

Q 3.2 Mon 10:45 BAR Schön

Bogoliubov Theory of Dipolar Bose-Einstein Condensates — •Aristeu R. P. Lima[1] and Axel Pelster[2] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

Nowadays, Bose-Einstein condensates with a weak anisotropic and long-range dipole-dipole interaction, such as ^{52}Cr condensates, are considered to be relatively well understood in terms of the Gross-Pitaevskii mean-field theory. Howerever, for highly magnetic atoms, such as dysprosium, or for strongly polar heteronuclear molecules, as for instance ^{40}K-^{87}Rb, quantum fluctuations in dipolar condensates could become relevant. To this end, we discuss at first the Lee-Huang-Yang correction to the sound velocity of a homogeneous dipolar condensate as derived from the Bogoliubov theory. In order to take the harmonic trapping potential into account, we extend our calculations with the help of the Bogoliubov-de Gennes theory. Thereby, we make use of the local density approximation to derive the Bogoliubov spectrum analytically, from which we determine then physical quantities of interest such as the condensate depletion and the quantum corrections to the low-lying excitation frequencies as well as to the time-of flight dynamics. Due to the delicate interplay between the dipolar interaction and the condensate geometry, we find that the influence of the quantum fluctuations can be strongly affected by the trap aspect ratio. Therefore, we are quite optimistic that future experiments will detect these beyond mean-field effects.

Q 3.3 Mon 11:00 BAR Schön

Semiclassical model for the formation of Rydberg molecules — •Andrej Junginger, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

In cold gases ultra-long range Rydberg molecules have been predicted theoretically [1] and recently observed experimentally [2]. The bond is caused by a scattering process of the Rydberg electron at the ground state atom. In a mean-field approximation this can be explained by a Fermi pseudo-potential which well describes the bound states but, as a conservative potential, is not able to explain the process of capturing the ground state atom.

We present a new model based on scattering theory and a semiclassical approximation which is capable of describing the formation of the Rydberg molecule by decelerating the ground state atom. From the infinite set of Kepler ellipses we select a finite number passing through the ground state atom. At the position of the latter the ellipses are approximated by plane waves, and the s-wave scattering of the Rydberg electron at the ground state atom then leads to a dissipative force. Solving the classical equations of motion, we find that a ground state atom with kinetic energy $E_{\mathrm{kin}} > 0$ in the order of the magnitude of the binding energy will always be decelerated. Depending on the initial conditions it can even come to rest, so that this dissipative process may play an important role in the formation of the Rydberg molecule.

[1] C. H. Green *et al.*, *Phys. Rev. Lett.* **85**, 2458 (2000).

[2] V. Bendkowsky *et al.*, *Nature* **458**, 1005 (2009).

Q 3.4 Mon 11:15 BAR Schön

Optical Manipulation of Large Molecule Beams for Molecule Interference — •Paul Venn and Hendrik Ulbricht — School of Physics and Astronomy, University of Southampton, Highfield, SO17 1BJ, UK

A challenge of molecule interferometry is being able to create intense beams of large molecules, which are typically created through sublimation in a furnace. In order to increase the intensity of the beam reaching our Talbot-Lau interferometer a molecular lens is proposed. This lensing effect relies on creating an off-resonant Stark shift in the target molecule species through the interaction with an intense laser beam directed perpendicular to the molecular beam. This lensing effect has previously been observed for light molecules such as CS2 and I2, and the effect is scalable up to much larger masses due to the non-resonant interaction. Simulations have been carried out modelling the lensing effect for our interferometer using a femtosecond pulsed Ti:Sa laser with 50kW peak power. From this we expect to observe a 25% increase in detected signal for a thermal beam of C60 using a single laser beam acting as a cylindrical molecular lens. For more highly polarizable molecules such as H2TPP we expect to be able to observe the focal spot of the lens without the need for preliminary cooling of the molecule beam. It is hoped that this lensing effect can be used on more massive fluro-fullerene molecules to allow us to measure interference for molecules of masses of up to 10,000amu. We will report on theoretical simulations as well as on experiments on this effect.

Q 3.5 Mon 11:30 BAR Schön

Low temperature studies of molecules in solid state using an optical nanofiber — •Ariane Stiebeiner, Nils Konken, David Papencordt, Ruth Garcia-Fernandez, and Arno Rauschenbeutel — Technische Universität Wien - Atominstitut, Stadionallee 2, 1020 Wien, Austria

Molecules in solids have proven to be a versatile system for studying quantum optical effects and for realizing single photon sources. Coupling the emitters to optical nanofibers further enhances the potential of this system. The strong radial confinement and the pronounced evanescent field of the guided light in optical nanofibers yield a high excitation and emission collection efficiency [1, 2]. We present low temperature studies on terrylene doped p-terphenyl crystals on the nanofiber waist of a tapered optical fiber. The high sensitivity of our method should allow us to perform single molecule spectroscopy and to realize an all-fiber-based single photon source.

We gratefully acknowledge financial support by the Volkswagen Foundation (Lichtenberg Professorship), the ESF (European Young Investigator Award), and the EC (STREP "CHIMONO").

[1] F. Warken et al., Optics Express, Vol. 15, 19, 11952-11958 (2007)
[2] A. Stiebeiner et al., Optics Express, Vol. 17, 24, 21704-21711 (2009)

Q 3.6 Mon 11:45 BAR Schön

Low Temperature Studies on Single Molecules interacting with Plasmonic Structures — •Bernhard Grotz[1], Ilja Gerhardt[1,2], Petr Siyushev[1], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]3rd Physics Institute and Research Center SCoPE, Universität Stuttgart, Germany — [2]Max Planck Institute for Solid State Research, Stuttgart, Germany

When light interacts with metal surfaces it excites electrons which can form propagating excitation waves called surface plasmon polaritons (SPP). These collective electronic excitations allow for many applications due to their ability to produce electric fields, localized to sub-wavelength scales. It was shown that the emission of single quantum systems like e.g. quantum dots [1] or nitrogen vacancy centres in diamond [2] can be used to generate propagating single surface plasmon polaritons. In the frame of large scale quantum networks, further conceived experiments incooperate the incoupling of single narrow-band emitters to plasmons. Such single emitters could be organic dye molecules serving as an element of e.g. a quantum phase gate. Here we present first experimental results on the coupling of single organic molecules to silver nanowires at cryogenic temperatures.

[1] A. V. Akimov, A. Mukherjee, C. L. Yu, D. E. Chang, A. S. Zibrov, P. R. Hemmer, H. Park & M. D. Lukin, Nature 450, 402-406 (2007)

[2] R. Kolesov, B. Grotz, G. Balasubramanian, R. J. Stöhr, A. A. L. Nicolet, P. R. Hemmer, F. Jelezko & J. Wrachtrup, Nature Physics 5, 470-474 (2009)

Q 3.7 Mon 12:00 BAR Schön

Interlayer superfluidity and scattering in bilayer systems of polar molecules — •Alexander Pikovski[1], Michael Klawunn[1,2], G. V. Shlyapnikov[3], and Luis Santos[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany — [2]INO-CNR BEC Center and Dipartimento di Fisica, Università di Trento, 38123 Povo, Italy — [3]Laboratoire de Physique Théorique et Modèles Statistiques, Université Paris Sud, CNRS, 91405 Orsay, France

We consider fermionic polar molecules in a bilayer geometry. The dipole-dipole interaction between molecules of different layers leads to the emergence of interlayer superfluids. The superfluid regimes range from BCS-like fermionic superfluidity to BEC of interlayer dimers. The system shows unusual two-dimensional scattering behaviour [M. Klawunn et al., Phys. Rev. A **82**, 044701 (2010)] and exhibits a peculiar BCS-BEC crossover [A. Pikovski et al., Phys. Rev. Lett. **105**, 215302 (2010)].

Q 3.8 Mon 12:15 BAR Schön

Controlling a Shape Resonance with Non-resonant Laser Light — •Ruzin Aganoglu[1], Mikhail Lemeshko[2], Bretislav Friedrich[2], Rosario González-Férez[3], and Christiane P. Koch[1,4] — [1]Freie Universität Berlin, Institut für Theoretische Physik — [2]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin — [3]Universidad de Granada, Facultad de Ciencias, Spain — [4]Universität Kassel, Institut für Physik

A shape resonance is a metastable state that arises from trapping of a part of the scattering wavefunction by the centrifugal barrier. It corresponds to an enhanced pair density of atoms at short internuclear separations, which can be useful for making molecules from atom pairs. For atoms confined in an atom trap, the pair density will be enhanced if the energy width of the resonance matches the atom trap temperature. Herein, we seek to control the energy of a shape resonance by making use of non-resonant laser light. Nonresonant light couples to the polarizability anisotropy of an atom pair and thereby modifies its rotational and vibrational states. We study the effect on the pair density of rubidium and strontium atoms as a function of the pulse duration and intensity of the nonresonant light.

Q 3.9 Mon 12:30 BAR Schön

Near-threshold vibrational bound states in long-range molecules — •Tim-Oliver Müller and Harald Friedrich — Physik Department, TU München, Germany

Interatomic potentials with attractive tails asymptotically vanishing as $-1/r^\alpha$ (with $\alpha > 2$) support at most a finite number of vibrational bound states, and their energies E_v are related to their quantum numbers v via a quantization rule $v_\mathrm{D} - v = F(E_v)$, where v_D is the – not necessarily integer – *threshold quantum number*. At near-threshold energies the *quantization function* $F(E)$ is predominantly determined by a contribution $F_\mathrm{tail}(E)$ stemming from the potential's tail, which is a universal function depending only on the power α. Quantum effects are important near the dissociation threshold and $F(E)$ differs significantly from the widely used semiclassical expression derived by LeRoy and Bernstein [1]. Explicit analytical expressions for F_tail have been presented for to the van der Waals interaction between two neutral polarizable atoms or molecules ($\alpha = 6$) [2] as well as for the dispersion energy occuring in certain diatomic molecular ions ($\alpha = 4$) [3] and recently also for the power $\alpha = 3$ [4], which corresponds to the resonant dipole-dipole interaction between two identical atoms in a homonuclear dimer. Applications to sodium dimers show the importance of correctly including quantum effects near threshold.

[1] R. J. LeRoy and R. B. Bernstein, *J. Chem. Phys* **52**, 3869 (1970).
[2] P. Raab and H. Friedrich, *Phys. Rev. A* **78**, 022707 (2008).
[3] P. Raab and H. Friedrich, *Phys. Rev. A* **80**, 052705 (2009).
[4] T.-O. Müller and H. Friedrich, submitted to *Phys. Rev. A*.

Q 3.10 Mon 12:45 BAR Schön

Quantum reflection and localization in bound systems — •Elias Diesen[1] and Jan-Michael Rost[2] — [1]Max-Planck-Institut für Physik komplexer Systeme — [2]Max-Planck-Institut für Physik komplexer Systeme

The phenomenon of quantum reflection is briefly presented and compared to the situation where a similar shape of the underlying potential causes localization of eigenstates in a confining potential. The relation of both these quantum phenomena to the breakdown of semiclassical (WKB) dynamics is discussed. A few physical systems that show such behaviour are presented, among them the ultracold Rydberg dimer, consisting of a ground state and a Rydberg atom [1]. Due to the current rapid development of experimental techniques for the ultracold regime, these phenomena should become more and more accessible to direct experimental investigation.

[1] V. Bendkowsky etal., Phys. Rev. Lett. 105, 163201 (2010).